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(54) PLASMATRON-INTERNAL COMBUSTION ENGINE SYSTEM

PLASMATRON BRENNKRAFTMASCHINENSYSTEM

SYSTEME CONSTITUE PAR UN MOTEUR A COMBUSTION INTERNE ET PAR UN PLASMATRON

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- **HYDROGEN ENERGY PROGRESS VI, vol.1, 20 July 1986, VIENNA,AUSTRIA pages 185 - 190 KASKEY G. ET AL. 'HYDROGEN PRODUCTION BY THE HULS PLASMA-REFORMING PROCESS' cited in the application**
- **AUTOMOTIVE ENGINEERING, no.8, 1 August 1985, WARRENDAL,PENSYLVANIA,USA pages 81 - 84 SCOTT & YAMAGUCHI 'HYDROGEN FUEL BREAKTHROUGH WITH ON DEMAND GAS GENERATOR'**

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Description

BACKGROUND OF THE INVENTION

This invention relates to rotary power systems including a plasmatron for supplying hydrogen-rich gas to an internal combustion engine.

Hydrogen is attractive as a fuel or additive for internal combustion engines because hydrogen as a fuel source can significantly reduce air pollution and can also serve as an alternative energy source to gasoline. See Mishchenko, A. I. et al., Proc. VII World Hydrogen Energy Conference, Vol. 3 (1988), Belogub, A. V. and G. B. Talda, Int. J. Hydrogen Energy, Vol. 16, 423 (1991), Varde, K.S. and L.K. Varde Hydrogen Energy Progress V, Vol. 4 (1984), Feucht, K.,W. Hurich, N. Komoschinski, and R. Povel, Int. J. Hydrogen Energy, Vol 13, 243 (1988), Chuveliov, A.V., In: *Hydrogen Energy and Power Generation,* T. Nejat Veziroglu, Ed., Nova Science Publisher, New York, New York (1991), Das, L. M., Int. J. Hydrogen Energy, Vol 16, 765 (1991). Moreover, engine efficiency can be 10-50% higher when running on hydrogen as compared with a gasoline engine. Prior art systems contemplated either storing hydrogen on-board or generating it on board. On-board storage requires high pressure vessels, cryogenic containers if the hydrogen is to be stored as a compressed gas or liquid, or large getter volumes and weights if the hydrogen is to be stored as a hydride. Moreover, the refill time for hydrogen is substantially longer than that for gasoline when the hydrogen is to be stored on-board.

As to the on-board production of hydrogen, several approaches have been disclosed in the prior art. For example, United States Patent No. 5,143,025 discloses the use of electrolysis to separate water into hydrogen and oxygen and introducing the hydrogen into an internal combustion engine. In United States Patent No. 5,159,900, hydrogen gas is produced by water interaction with solid carbon. Electrical current is passed between the carbon electrodes causing the electrodes to burn and oxidize to form carbon monoxide and hydrogen. U.S. Patent No. 5,207,185 discloses a burner which utilizes a portion of the hydrocarbon fuel to reform another portion to produce hydrogen. The hydrogen is then mixed with the hydrocarbon fuel for introduction into an internal combustion engine.

Another system diverts a fraction of the gasoline from the flow path to the engine and is passed through a catalytic converter and decomposed to yield hydrogen-rich gas. See, Breshears, R., Cotrill, H. and Rupe, J., Proc. of EPA 1st Symposium on Low Pollution Power Systems Development, 268 (1973). We note that the authors state that this catalytic converter system would not be practical to generate hydrogen as the sole fuel for an engine. This article also suggests other techniques for generating hydrogen on-board a vehicle. Yet another system of this type uses partial oxidation in a catalytic converter to produce hydrogen rich gas. See Houseman, J. and Voecks, G.E., Proc. 3rd World Hydrogen Energy Conf., 949 (1980). This system requires carefully controlled catalytic action and temperature range and has limitations for startup and transient response.

US Patent No. 4,036,181 discloses a fuel converter using radiant energy from heated graphite rods to convert hydrocarbon fuels into combustible mixtures such as carbon black and hydrogen or carbon monoxide and hydrogen. The converted fuels are introduced into an internal combustion engine. The reference, however, does not teach or suggest the use of a plasmatron to produce hydrogen-rich gas.

SUMMARY OF THE INVENTION

The rotary power system of the invention includes a source of hydrocarbon fuel and a plasmatron for receiving the hydrocarbon fuel and reforming it into a hydrogen-rich gas. An internal combustion engine receives the hydrogen-rich gas from the plasmatron and a generator powered by the engine delivers electrical energy to operate the plasmatron. Optionally, the engine is connected to receive hydrocarbon fuel directly in addition to the hydrogen rich gas. Thus, the system can be readily switched from 100% hydrocarbon fuel to a mode in which hydrogen-rich gas serves as an additive to the hydrocarbon fuel and then to operation with 100% hydrogen-rich gas. In preferred embodiments, the plasmatron is a water plasmatron utilizing steam reforming of the hydrocarbon source fuel. In another embodiment, the plasmatron is used in a partial oxidation reforming mode.

Because the plasmatron is highly efficient and also because there is the option to operate in a mode where only part of the hydrocarbon fuel is converted into hydrogen-rich gas, the overall system efficiency remains high even though mechanical energy from the engine is used to power the plasmatron. Based on prior art studies conducted utilizing hydrogen to power internal combustion engines, pollutants can be reduced dramatically. The suitably designed plasmatron according to the invention provides an efficient and compact unit to produce hydrogen-rich gas from gasoline, diesel, and other fuels. The plasmatron utilizes electrical heating of ionized gases, providing a highly controllable means to process hydrocarbon fuel. Use of the plasmatron to produce hydrogen-rich gas eliminates the need for on-board hydrogen storage on motor vehicles and will significantly improve the vehicles' working characteristics without any radical modification of engine design and fuel equipment. In addition to producing hydrogen-rich gas for the engine, the plasmatron provides a means of injecting high temperature combustible gas into the engine which can further increase completeness of combustion thereby further reducing pollutants.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a cross-sectional view of a water plasmatron for use in the present invention.

Fig. 2 is a block diagram illustrating the use of hydrogen-rich gas from a plasmatron as an additive to gasoline for an internal combustion engine.

Fig. 3 is a block diagram illustrating use of hydrogen-rich gas from the plasmatron as the sole fuel for an internal combustion engine.

Fig. 4 is a block diagram illustrating intermittent plasmatron use.

Fig. 5 is a block diagram illustrating operation of a plasmatron internal combustion engine system with different kinds of fuels.

Fig. 6 is a block diagram illustrating use of hydrogen-rich gas from a plasmatron in a hybrid, zero emission vehicle.

Fig. 7 is a block diagram of energy and mass flow in the system.

Fig. 8. is a cross-sectional view of a partial oxidation plasmatron which is vortex and magnetically stabilized.

Fig. 9 is a cross-sectional view of a partial oxidation plasmatron having a concentric electrode design.

Fig. 10 is a block diagram illustrating a plasmatron as an additional preheat source for a conventional partial oxidation reformer.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A key aspect of the present invention is a compact plasmatron or reformer which uses a plasma -- an electrically heated gas -- to convert hydrocarbon fuels into hydrogen- rich gases. One suitable configuration of a compact plasmatron is shown in Fig. 1. A plasmatron 10 includes a cylindrical cathode 12 and an anode 14. Upon energization, a plasma arc 16 is created across the anode 14 and cathode 12. Water 18 resides in the region between the cathode 12 and anode 14 and is fed in through a channel 20. A magnetic coil 22 serves to rotate the arc 16 so that it does not erode the electrodes 12 and 14. An illustrative water plasmatron 10 is described in more detail in USSR Patent No. 700935 issued August 1979. See also, Kaskey G. et al., Hydrogen Production by the Huls Plasma-Reforming Process, Hydrogen Energy Progress VI, Vol. 1, July (1986) which describes large-scale plasmatron use. It is expected that compact plasmatrons can produce hydrogen-rich gases from gasoline and other hydrocarbon fuels with greater than 90% efficiency (conversion of electricity into thermal processing energy). The hydrogen content of gas is maximized in a water plasmatron in which steam is the working gas. The plasmatron output can be 75-80% H_2 and 20-25% CO. Other configurations of plasmatrons could also be used such as described by D.R. MacRae in Plasma Chemistry and Plasma Processing, Vol. 9, No. 1, 1989.

In the plasmatron 10, a mixture of hydrocarbon fuel, hydrogen and water is heated in the plasma 16 to 1,000-3,000°C at atmospheric pressure. The high temperature achieved in the plasma increases the desired reaction rates resulting in highly efficient conversion of hydrocarbon fuels into hydrogen-rich gas without the use of catalysts. As a result of the large reaction rates in the plasmatron 10, the size of the plasmatron reformer is substantially decreased making it an ideal component in a vehicular system.

Gaseous or liquid hydrocarbons are converted by steam in the plasma by the reaction:

$$C_mH_n + mH_2O \rightarrow mCO + (n/2+m)H_2 \quad (1)$$

(where m and n represent the relative amounts of carbon and hydrogen) producing a hydrogen-rich gas. Temperatures in the 1,000-1,700°C range are required by the reaction kinetics. See, for example, Suris, A.L., *Handbook of the Thermodynamic High Temperature Process Data* (1987). Since it has been demonstrated that the addition of hydrogen to gasoline results in a very complete oxidation of the gasoline, it is also to be expected that the carbon monoxide, CO, would be completely burned. Since the high temperature and substantial hydrogen concentration of plasma gas will improve the efficiency of combustion in the engine it should be possible to utilize lower cost, low octane fuel instead of more expensive, high quality gasoline. Moreover, the plasmatron can process other fuels for internal combustion engines in addition to gasoline. These fuels include ethanol, methanol, natural gas, JP4 and possibly oil and biomass. The capability of the plasmatron to process different fuels provides the option of using fuel from one tank for the generation of hydrogen-rich gas and combining the hydrogen-rich gas with gasoline or some other fuel from another tank.

An illustrative plasmatron system for vehicular application weighs less than approximately 30 kilograms and has a length of approximately 30 centimeters. Plasmatron power levels are in the range of a few kilowatts. The plasmatron 10 can be used in continuous or intermittent operation to optimize performance. A small amount of hydrogen is stored in the intermittent operation mode.

With reference now to Fig. 2, the hydrogen-rich gas from the plasmatron 10 is introduced into an internal combustion engine 30 of conventional design. It is well understood by those skilled in the art how to modify an internal combustion engine to operate on a mixture of hydrogen gas and gasoline or entirely on hydrogen gas. As shown in Fig. 2, in addition to the hydrogen-rich gas from the plasmatron, hydrocarbon fuel 32 is introduced into the engine 30 as well. Some of the mechanical energy produced by the engine 30 is used to run a generator/battery system 34, the electrical output of which is connected to the plasmatron 10 for its operation. As discussed in copending application serial no.08/089,038 filed July 9, 1993, the plasmatron 10 requires on the order of 100 volts for its operation.

With reference now to Fig. 3, the plasmatron 10 generates hydrogen-rich gas which is the sole fuel input to the engine 30. Note that a combustion product of hydrogen, H_2O, is supplied to the plasmatron 10 for its operation. As shown in Fig. 4, the plasmatron 10 may be operated continuously or intermittently. The hydrogen rich gas can be stored in a gas storage container 36 allowing the plasmatron to operate where it is most efficient. Gas from the gas storage container 36 is introduced into the engine 30 for use under variable load conditions.

The plasmatron 10 (see Fig. 5) can operate on a variety of fuels. Hydrocarbon fuel in a tank 40 may be, for example, low octane, less expensive gasoline. A higher octane gasoline is stored in a second hydrocarbon fuel tank 38. In this mode of operation, the higher quality fuel is reformed into hydrogen-rich gas in the plasmatron 10 and then introduced into the engine 30. Simultaneously, lower quality, less expensive, fuel is delivered to the engine 30 from the tank 40. A hydrogen-rich gas from the plasmatron 10 can be used for the gasoline engine 30 in a hybrid vehicle (see Fig. 6). A hybrid vehicle might use a gasoline engine 30 which is most efficient at steady speeds for sustained highway travel and batteries 42 for city driving.

The prior art has recognized that by optimizing hydrogen-conventional fuel mixtures in an internal combustion engine, it is possible to significantly decrease NO_x and CO by factors of 2-10; CO and NO_x reductions by factors of 5 and 8, respectively, were obtained with hydrogen addition as low as 7% by mass. See the Chuveliov reference cited earlier. Studies of the effect of hydrogen addition on gasoline engine truck operation in town driving were made with engine operation that used a variable amount of hydrogen mass fraction as set forth in the Belogub et al. article cited above. The mass fraction varied from approximately 4% to 20% depending upon engine load. Results from these studies are shown in Table 1:

Table 1

Effects of Hydrogen Addition Upon Gasoline Engine Performance						
				Toxic Components		
Fuel	Payload kg	Petrol Consumption 1 per 100 km	H_2 Consumption kg per 100 km	CO	g $kW^{-1}h^{-1}$ CH	NO_x
Petrol	300	34.6		86.3	2.98	14.8
	4000	38.3				
Petrol/H_2	300	20.3	2.155	9.35	1.57	2.08
	4000	23.2	2.305			

The average mass fraction of hydrogen $m_h/(m_h+m_g)$ where m_h is the hydrogen mass and m_g is the mass of gasoline was 12%. The fuel efficiency (related to the energy content of the gasoline and hydrogen) was 17.5% higher for engine operation with the hydrogen additive relative to operation with gasoline alone.

Due to the many variables involved in internal combustion engine operation, the quantative advantages obtained through the addition of hydrogen can vary substantially. Very large reductions in No_x are possible through extremely lean engine operation made possible by the use of hydrogen as set forth in the Breshears article cited above. For diesel engines, hydrogen addition slightly increases the NO_x and HC emissions while decreasing the CO and smoke and increasing the efficiency.

The overall system efficiency of the invention can be projected by an energy balance. Fig. 7 shows an illustrative energy and mass flow diagram for the system. In Fig. 7, the variable x is the mass fraction of gasoline into the plasmatron; ρ_r, the ratio of the heating value of hydrogen-rich gas and gasoline, is equal to 1.3. A given mass of gasoline (or some other fossil fuel) is combined with hydrogen-rich gas to create an energy value equivalent of 12% mass fraction of hydrogen. This mass is the average value set forth above in Table 1. The hydrogen-rich gas is produced from gasoline by the plasmatron 10. For example, for the case of around 12% addition of hydrogen gas by mass mentioned previously, the amount of energy that must be added to the gasoline is 16.8 MJ/kg gasoline. This amount of energy would be produced by a 62% mass addition of hydrogen-rich gas. To produce this amount of hydrogen-rich gas it is necessary to process an additional 28% of gasoline according to equation 1.

The electrical energy requirement for the plasmatron 10 to process a given amount of hydrocarbon fuel can be given by the ratio parameter:

$$Rg=\frac{E_g}{E_p} \quad (2)$$

where E_g is the chemical energy content of the gasoline that is processed and E_p is the electrical energy requirement of the plasmatron.

The value of R_g is determined from the specific power requirement for equilibrium steam conversion of liquid hydrocarbons. See, Suris, A.L., *Handbook of the Thermodynamic High Temperature Process Data* (1987). There is a wide range of R_g values that could be applicable. R_g is between 3 and 4 for different grades of gasoline. R_g is 5.7 for methanol. Using the value of R_g = 3.5 in Eq. (2), the electrical energy requirement of the plasmatron is then 1/3.5 E_g.

As mentioned previously, for a given amount of gasoline that is used in the internal combustion engine 30, an amount of gasoline which is approximately 28 percent as much (0.28Mg) must be processed by the plasmatron 10 to produce the required hydrogen. Therefore, the required plasmatron 10 energy to add 12 percent hydrogen by mass is:

$$E_p=\frac{0.28E_g}{R_g} \quad (3)$$

or

$$E_p=\frac{0.28E_g}{3.5}=0.08E_g$$

The mechanical energy requirement to operate the generator 34 that runs the plasmatron 10 depends upon E_p and η_{gen} where η_{gen} is the generator 34 efficiency. For η_{gen} = 0.9, the mechanical energy needed to run the plasmatron 10 is:

The net mechanical energy available for powering a vehicle is:

$$E_{mech,\ plasma}=\frac{Ep}{0.9}=\frac{0.08E_g}{0.9}=0.09E_g$$

$$E_{mech,net}=\eta_e\,(1.36E_g)-\frac{E_{plas}}{\eta_{gen}} \quad (4)$$

where η_e is the thermal efficiency of the engine 30. The heating value of the fuel that goes into the engine, 1.28 units of gasoline, is increased by the energy added to the 0.28 units with the energy provided by reformation. The total heating value is: $1 + 0.28 \times \rho_{reformer} = 1+0.28 \times 1.3 = 1.36$, where $\rho_{reformer}$ is the ratio between the heating value of hydrogen-rich gas and gasoline.

Combining (3) and (4),

$$E_{mech,\ net}=\eta_e\,(1.36E_g)\,(1-\frac{0.28/1.36}{R_g\eta_e\eta_{gen}}) \quad (5)$$

If η_e = 0.25 and η_{gen} = 0.9 and R_g = 3.5 (5) becomes:

$$E_{mech,net}=\eta_e\,(1.36E_g)\,(1-0.26)$$

or $E_{mech,net} = 0.74\ \eta_e\ (1.36\ E_g) = 0.25\ E_g$.

The overall fuel economy of the hydrogen additive engine 30 embodiment is the net mechanical energy divided by the amount of fuel:

$$(fuel\ efficiency)_{\mathrm{H_2+gas}} = E_{mech,net}/1.28\,m_g = 0.20\,\frac{E_g}{m_g} \qquad (6)$$

In contrast, for an engine operating with pure gasoline, it can be assumed that the thermal efficiency would be 17.5 percent lower (Table 1) and that the fuel efficiency of gasoline-only engine operation would be 0.21 E_g/m_g. Thus under these assumptions, the addition of hydrogen-rich gas could result in almost the same overall fuel efficiency.

In addition, operation on 100 percent hydrogen-rich gas, either continuously or at selected periods of time, could be attractive for certain special situations.

In general, a variety of tradeoffs between hydrogen mass fraction, compression ratio, timing, and overall system efficiency may provide more optimum operating parameters.

Using advanced control technology (already implemented in modern fuel injected vehicles), it is possible to develop an engine system where operation can be readily switched during driving between 100% gasoline operation, hydrogen additive operation and 100% hydrogen-rich gas operation.

If overall fuel efficiency were, in fact, to be significantly lowered, one option is for vehicles to use the plasmatron-hydrogen pollution reduction option when operating in cities and bypass it when operating in the countryside where NO_x and CO concentrations are lower. A further option is to use the plasmatron-generated hydrogen mainly at rpm ratings, engine temperature and outside air pressure and humidity where exhaust emissions are the largest, where control would have the greatest impact.

The plasmatron-internal combustion engine system will also be useful for hybrid vehicles that use a combination of battery-generated electrical power and an internal combustion engine. In hybrid vehicles, the internal combustion engine can be operated at loads which maximize efficiency (η_e). However, in ordinary operation with gasoline, there can still be significant amounts of undesirable engine emissions. Use of a plasmatron to produce hydrogen-rich gas would reduce these emissions. Moreover, because the engine would be operating at high efficiency, the effect of the plasmatron electricity requirement on overall power balance would be minimized. In addition, the presence of a significant battery capability in the hybrid vehicle would allow more flexibility in operation of the plasmatron. Operation of the plasmatron for producing 100 percent hydrogen-rich gas would be facilitated. Thus use of a plasmatron-hybrid vehicle system might provide capability approaching zero emission of hydrocarbons, NO_x and CO. In addition, there would be greater flexibility in operating on different types of fuel.

In yet another aspect of the invention, the plasmatron is used in a partial oxidation reforming mode rather than as a water plasmatron. In this mode, the plasmatron is employed to provide the optimal temperature for a rich mixture of hydrocarbon fuel and air. The reaction in a partial oxidation plasmatron is:

$$C_mH_n + \frac{m}{2}\left(O_2 + \frac{79}{21}N_2\right) \rightarrow mCO + \frac{n}{2}H_2 + \frac{m}{2}\frac{79}{21}N_2$$

Since this plasmatron reaction is exothermic it is possible to use it in modes where less energy is required as compared to steam reforming. A greater range of operating conditions is possible and there is no decrease in overall system efficiency. The plasmatron provides well controlled heating which, in conjunction with the heat provided by the exothermic reaction and any other heat provided by exhaust gases or additional combustion, produces the optimal temperature for reforming. Use is made of high temperature plasmatron off-gas for preheating the initial feed stock reagents.

NO_x production in the partial oxidation plasmatron is inhibited by the rich fuel mixture in a strongly reducing environment. Use of plasmatron heating allows rapid startup and gas flow rate variation of a partial oxidation reforming system. The partial oxidation plasmatron can be used to provide the optimal temperature for reforming both with and without a catalyst to speed up reaction rates.

With reference now to Fig. 8, a partial oxidation plasmatron **50** includes a water cooled cathode **52** which is made preferably from Zr or Hf which have high electron emissivities in oxidizing atmospheres. An anode **54** is electrically insulated from the cathode **52** structure by insulators **56.** A magnetic coil **58** is provided for rotating and stabilizing an arc **60.** Air is introduced tangentially at **62** in order to rotate the plasma arc **60.** A hydrocarbon is introduced at **64** and mixes with the air introduced through the port **62**. Reformed gases are passed into a heat exchanger **66** which serves to preheat air introduced into the plasmatron **50** through the port **62**.

With reference now to Fig. 9, a partial oxidation plasmatron **70** having a concentric electrode design is illustrated. In this embodiment, a copper, water cooled electrode **72** has a coaxial configuration and can utilize different types of working gases as well as an air-hydrocarbon mixture. An arc **74** spans the region between the cathode **72** and a water cooled anode **76.** In this embodiment, a hydrocarbon is introduced through a port **78** and air is introduced through a port **80.** The hot off-gasses pass through a heat exchanger **66** and air is preheated before entering the plasmatron **70** through the port **80.**

It is also contemplated to use a plasmatron to provide controllable preheat to a conventional partial oxidation reformer (which uses combustion heating with or without a catalyst). Such a system configuration is illustrated in Fig. 10. The plasmatron can also be used in parallel with a conventional reformer or an onboard storage source of hydrogen. The plasmatron would be used at times when these sources are not adequate to vehicular needs.

It is thus seen that a plasmatron hydrogen-rich gas generator internal combination engine system can provide substantial reductions in NO_x and CO emissions and would facilitate the use of fuels other than gasoline. Key features of the system are the possibility of modest or no loss in overall fuel efficiency due to the high efficiency of the plasmatron, the increase in engine efficiency with the use of hydrogen-rich gas, and the option for use of hydrogen as an additive rather than as the entire fuel.

The major contributor to air pollution in the U.S. is the fossil-fuel powered motor vehicle. In 1987, 66 percent of the carbon monoxide emission, 43 percent of NO_x emissions, and 20 percent of particle emissions came from motor vehicles alone. The water or partial oxidation plasmatron engine system of the invention for improving fuel combustion in internal combustion engines will have a significant effect on improving air quality.

Claims

1. Rotary power system comprising:

a source of hydrocarbon fuel;
a plasmatron (10) for receiving the hydrocarbon fuel and reforming it into a hydrogen-rich gas;
an internal combustion engine (30) adapted to receive the hydrogen-rich gas from the plasmatron (10); and
a generator (34) powered by the engine (30) and connected to deliver electrical energy to power the plasmatron (10).

2. The system of claim 1 wherein the engine (30) is connected to receive the hydrocarbon fuel in addition to the hydrogen-rich gas.

3. The system of claim 1 or 2 wherein the plasmatron (10) is a water plasmatron.

4. The system of any preceding claim further including a gas storage tank (36) for receiving hydrogen-rich gas from the plasmatron (10) and delivering hydrogen-rich gas to the internal combustion engine (30).

5. The system of any preceding claim further including switching apparatus for selecting the relative proportion of hydrogen-rich gas and hydrocarbon fuel entering the engine (30).

6. Rotary power system as claimed in claim 1 comprising:

a further source (40) of hydrocarbon fuel;
the internal combustion engine (30) also being adapted to receive hydrocarbon fuel from the further source (40) of hydrocarbon fuel;
a generator (34) powered by the engine (30) and connected to deliver electrical energy to power the plasmatron (10).

7. Rotary power system as claimed in claim 1 in which:

the plasmatron (10) for receiving the hydrocarbon fuel and reforming it into a hydrogen-rich gas is compact;
the generator is part of a generator/motor; and the system includes
a battery connected to receive electrical energy from the generator/motor, a portion of electrical energy being supplied to the plasmatron (10).

8. Rotary power system of claim 7 wherein the generator/motor works as an electric motor receiving electrical energy from the battery to generate mechanical energy.

9. The system of claim 1 wherein the plasmatron (10) is a partial oxidation plasmatron.

10. The system of claim 9 wherein the partial oxidation plasmatron (10) is vortex and magnetically stabilized.

11. The system of claim 9 wherein the partial oxidation plasmatron (10) includes a concentric electrode design.

12. The system of claim 1 further including a heat exchanger for receiving off-gasses from the plasmatron (10) and for preheating air or water introduced into the plasmatron (10).

13. The system of claim 10 wherein the plasmatron includes a cathode made from a material selected from the group of Zr and Hf.

14. The system of claim 1 further including a battery for startup and transient operation of the plasmatron (10).

15. The system of claim 1 further including an additional on board production or storage source of hydrogen-rich gas.

Patentansprüche

1. Drehstromsystem bestehend aus oder enthaltend:

   eine Kohlenwasserstoffbrennstoffquelle;

   ein Plasmatron (10) für die Aufnahme des Kohlenwasserstoffbrennstoffs und Reformieren desselben zu einem wasserstoffreichen Gas;

   eine für die Aufnahme des wasserstoffreichen Gases aus dem Plasmatron (10) eingerichtete Brennkraftmaschine (30); und

   einen durch die Kraftmaschine (30) angetriebenen Generator (34), der für die Zufuhr elektrischer Energie zum Antreiben des Plasmatrons (10) angeschlossen ist.

2. System nach Anspruch 1, worin die Kraftmaschine (30) für die Aufnahme des Kohlenwasserstoffbrennstoffs zusätzlich zum wasserstoffreichen Gas angeschlossen ist.

3. System nach Anspruch 1 oder 2, worin das Plasmatron (10) ein Wasserplasmatron ist.

4. System nach einem der vorhergehenden Ansprüche, das weiterhin einen Gaslagertank (36) für die Aufnahme von wasserstoffreichem Gas aus dem Plasmatron (10) und die Zufuhr von wasserstoffreichem Gas zur Brennkraftmaschine (30) umfaßt.

5. System nach einem der vorhergehenden Ansprüche, das weiterhin eine Schaltvorrichtung umfaßt für die Wahl des relativen Verhältnisses von wasserstoffreichem Gas und Wasserstoffbrennstoff, in die die Kraftmaschine (30) eintreten.

6. Drehstromsystem nach Anspruch 1, bestehend aus oder enthaltend:

   eine weitere Kohlenwasserstoffbrennstoffquelle (40) ;

   die auch für die Aufnahme von Kohlenwasserstoffbrennstoff aus der zusätzlichen Kohlenwasserstoffbrennstoffquelle (40) eingerichtete Brennkraftmaschine (30);

   einen durch die Kraftmaschine (30) angetriebenen Generator (34), der für die Zufuhr elektrischer Energie zum Antreiben des Plasmatrons (10) angeschlcssen ist.

7. Drehstromsystem nach Anspruch 1, worin:

   das Plasmatron (10) für die Aufnahme des Kohlenwasserstoffbrennstoffs und Reformieren desselben zu einem kohlenwasserstoffreichen Gas kompakt ist;

der Generator Teil eines Generator/Motors ist; und

das System eine Batterie umfaßt, die für die Aufnahme elektrischer Energie vom Generator/Motor angeschlossen ist, wobei ein Teil der elektrischen Energie dem Plasmatron (10) zugeführt wird.

8. Drehstromsystem nach Anspruch 7, in dem der Generator/Motor als Elektromotor arbeitet, der von der Batterie elektrische Energie aufnimmt, um mechanische Energie zu erzeugen.

9. System nach Anspruch 1, worin das Plasmatron (10) ein Teiloxidationsplasmatron ist.

10. System nach Anspruch 9, worin das Teiloxidationsplasmatron (10) wirbel- und magnetisch stabilisiert ist.

11. System nach Anspruch 9, worin das Teiloxidationsplasmatron (10) eine konzentrische Elektrodenanordnung aufweist.

12. System nach Anspruch 1, das weiterhin einen Wärmetauscher umfaßt zur Aufnahme von Abgasen aus dem Plasmatron (10) und zur Vorwärmung von in das Plasmatron (10) eingeleiteter Luft oder eingeleitetem Wasser.

13. System nach Anspruch 10, worin das Plasmatron eine aus einem Material der Gruppe Zr und Hf gefertigte Kathode umfaßt.

14. System nach Anspruch 1, das weiterhin eine Batterie für Inbetriebnahme und Übergangsbetrieb des Plasmatrons (10) umfaßt.

15. System nach Anspruch 1, das weiterhin eine zusätzliche Quelle für die Produktion an Bord oder Lagerung von wasserstoffreichem Gas umfaßt.

Revendications

1. Système énergétique rotatif comprenant :

   une source de combustible hydrocarbure ;
   un plasmatron (10) pour recevoir le combustible hydrocarbure et le reformer en un gaz riche en hydrogène ;
   un moteur à combustion interne (30) adapté pour recevoir le gaz riche en hydrogène du plasmatron (10) ; et
   une génératrice (34) actionnée par le moteur (30) et reliée pour délivrer de l'énergie électrique pour alimenter le plasmatron (10).

2. Système selon la revendication 1 dans lequel le moteur (30) est relié pour recevoir le combustible hydrocarbure en plus du gaz riche en hydrogène.

3. Système selon la revendication 1 où 2 dans lequel le plasmatron (10) est un plasmatron à eau.

4. Système selon n'importe laquelle des revendications précédentes comprenant de plus un réservoir (36) de stockage de gaz pour recevoir du gaz riche en hydrogène du plasmatron (10) et délivrer du gaz riche en hydrogène au moteur à combustion interne (30).

5. Système selon n'importe laquelle des revendications précédentes comprenant de plus un appareil de commutation pour sélectionner la proportion relative de gaz riche en hydrogène et de combustible hydrocarbure entrant dans le moteur (30).

6. Système énergétique rotatif selon la revendication 1 comprenant :

   une autre source (40) de combustible hydrocarbure ;
   le moteur à combustion interne (30) étant également adapté pour recevoir du combustible hydrocarbure de l'autre source (40) de combustible hydrocarbure ;
   une génératrice (34) entraînée par le moteur (30) et reliée pour délivrer de l'énergie électrique pour alimenter le plasmatron (10).

7. Système énergétique rotatif selon la revendication 1 dans lequel:

le plasmatron (10) pour recevoir le combustible hydrocarbure et le reformer en gaz riche en hydrogène est compact ;
la génératrice est une partie d'un ensemble généretrice/motor ; et le système comprend
une batterie reliée pour recevoir de l'énergie électrique de l'ensemble généretrice/motor, une partie de l'énergie électrique étant fournie au plasmatron (10).

8. Système énergétique rotatif selon la revendication 7 dans lequel l'ensemble génératrice/motor fonctionne en tant que moteur électrique recevant de l'énergie électrique de la batterie pour générer de l'énergie mécanique.

9. Système selon la revendication 1 dans lequel le plasmatron (10) est un plasmatron d'oxydation partielle.

10. Système selon la revendication 9 dans lequel le plasmatron d'oxydation partielle (10) est stabilisé magnétiquement et en tourbillon.

11. Système selon la revendication 9 dans lequel le plasmatron d'oxydation partielle (10) comporte une structure d'électrode concentrique.

12. Système selon la revendication 1 comprenant de plus un échangeur de chaleur pour recevoir des effluents gazeux du plasmatron (10) et pour préchauffer de l'air ou de l'eau introduit dans le plasmatron (10).

13. Système selon la revendication 10 dans lequel le plasmatron comprend une cathode faite d'un matériau sélectionné dans le groupe de Zr et Hf.

14. Système selon la revendication 1 comprenant de plus une batterie pour le démarrage et un actionnement momentané du plasmatron (10).

15. Système selon la revendication 1 comprenant de plus une source de stockage ou de production incorporée supplémentaire de gaz riche en hydrogène.

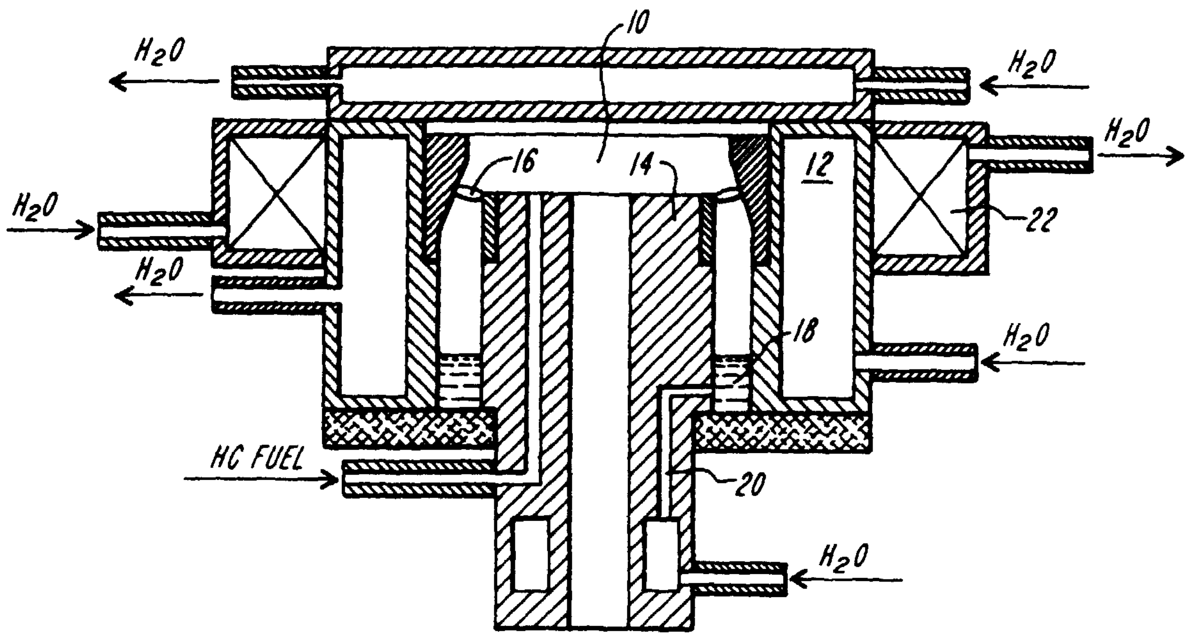
10
H2O
H2O
H2O
H2O
16
14
12
22
H2O
18
H2O
HC FUEL
20
H2O

FIG. 1

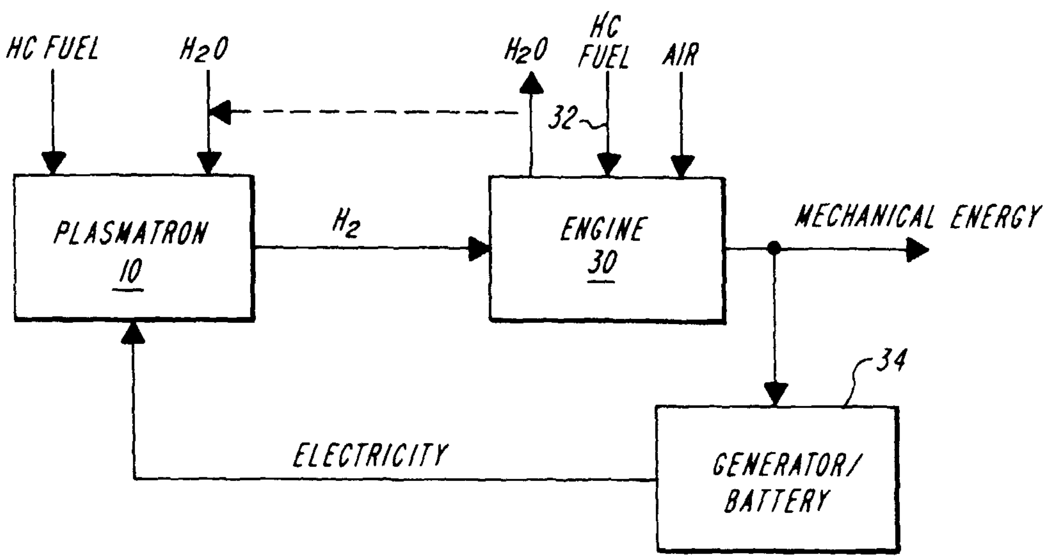
HC FUEL
H2O
H2O
HC FUEL
AIR
32
PLASMATRON
10
H2
ENGINE
30
MECHANICAL ENERGY
34
ELECTRICITY
GENERATOR/ BATTERY

FIG. 2

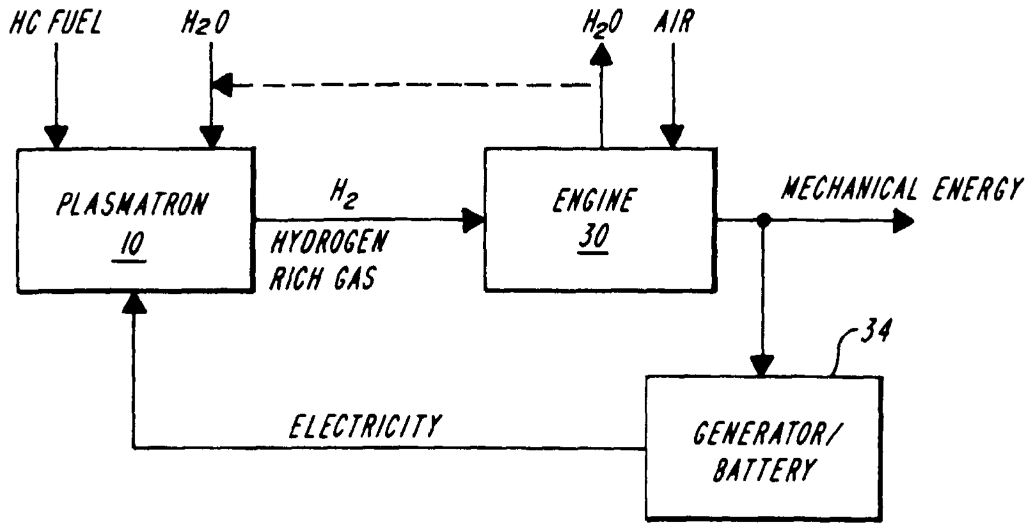
HC FUEL
H_2O
H_2O
AIR
PLASMATRON
10
H_2
HYDROGEN
RICH GAS
ENGINE
30
MECHANICAL ENERGY
34
ELECTRICITY
GENERATOR/
BATTERY

FIG. 3

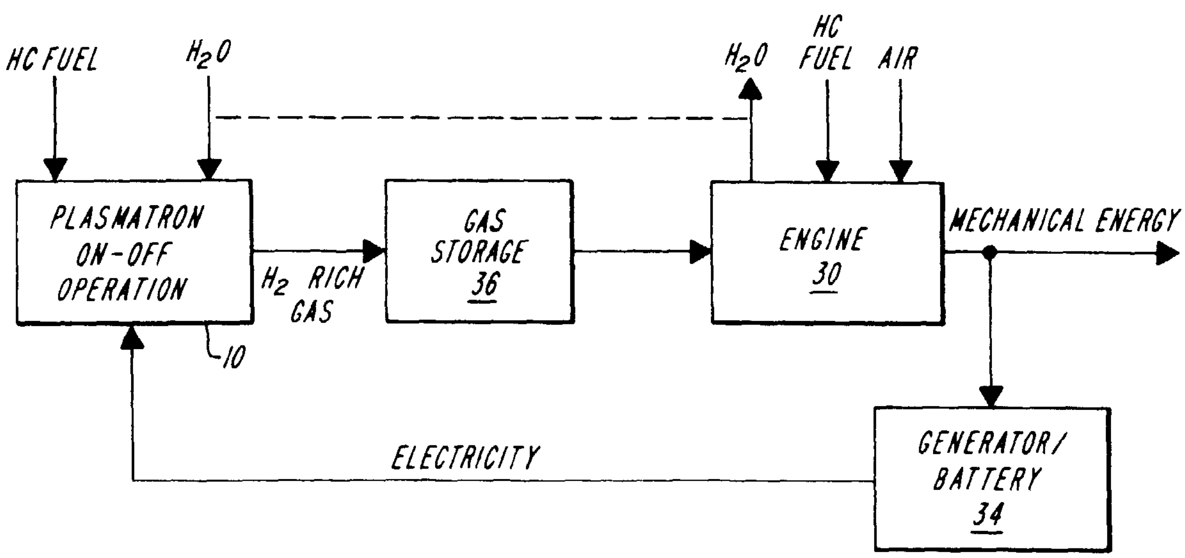
HC FUEL
H_2O
H_2O
HC
FUEL
AIR
PLASMATRON
ON-OFF
OPERATION
10
H_2 RICH
GAS
GAS
STORAGE
36
ENGINE
30
MECHANICAL ENERGY
ELECTRICITY
GENERATOR/
BATTERY
34

FIG. 4

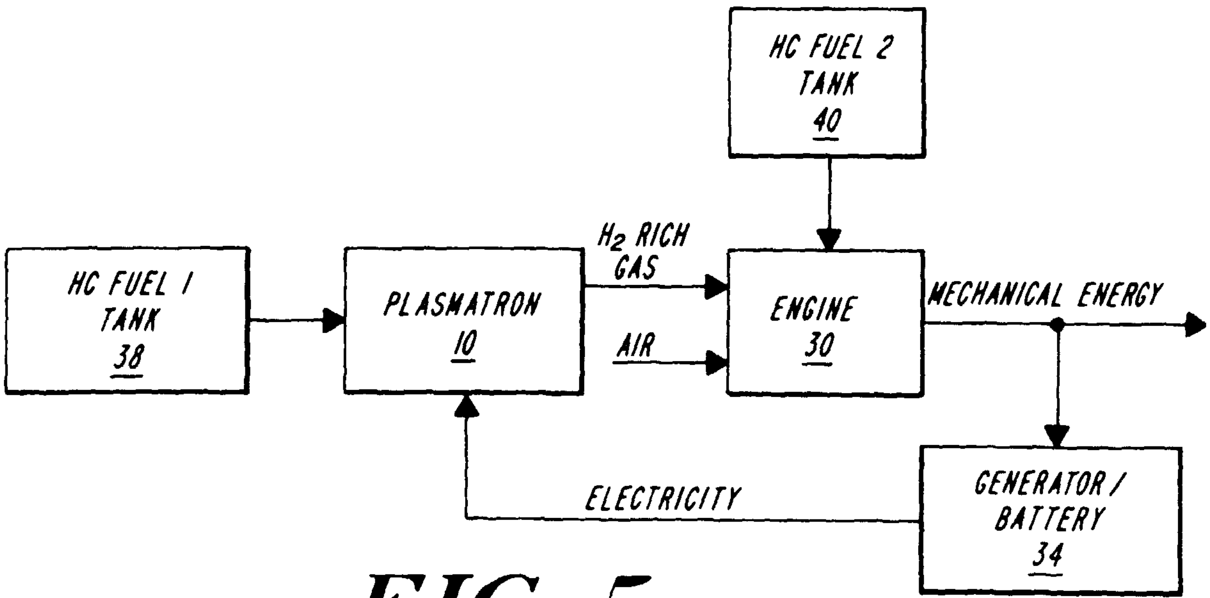
HC FUEL 2
TANK
40
HC FUEL 1
TANK
38
PLASMATRON
10
H_2 RICH
GAS
AIR
ENGINE
30
MECHANICAL ENERGY
GENERATOR /
BATTERY
34
ELECTRICITY

FIG. 5

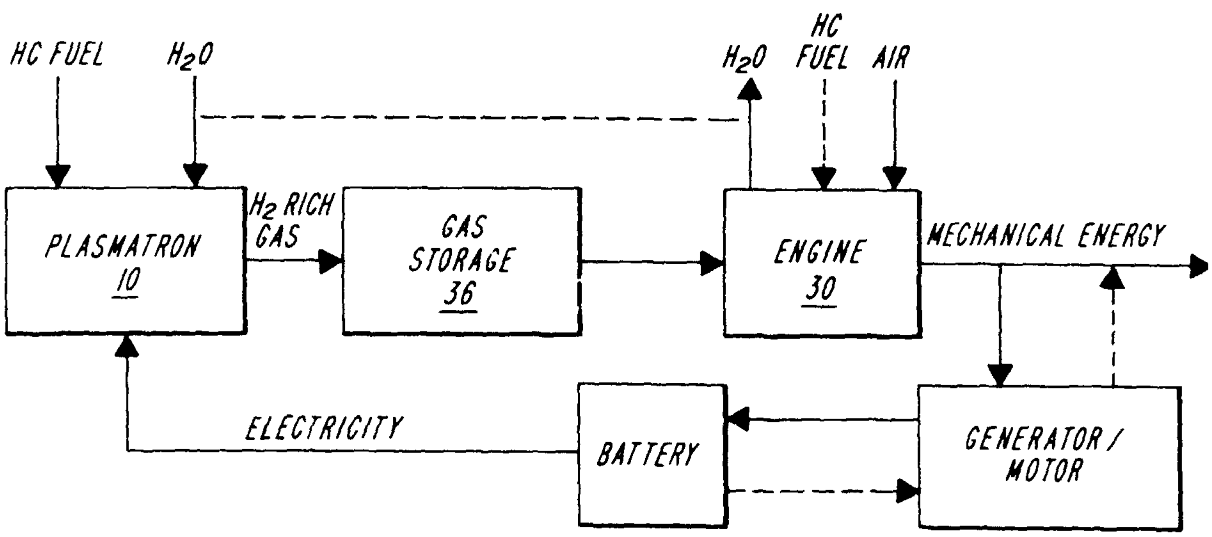
HC FUEL
H_2O
H_2O
HC
FUEL
AIR
PLASMATRON
10
H_2 RICH
GAS
GAS
STORAGE
36
ENGINE
30
MECHANICAL ENERGY
ELECTRICITY
BATTERY
GENERATOR /
MOTOR

FIG. 6

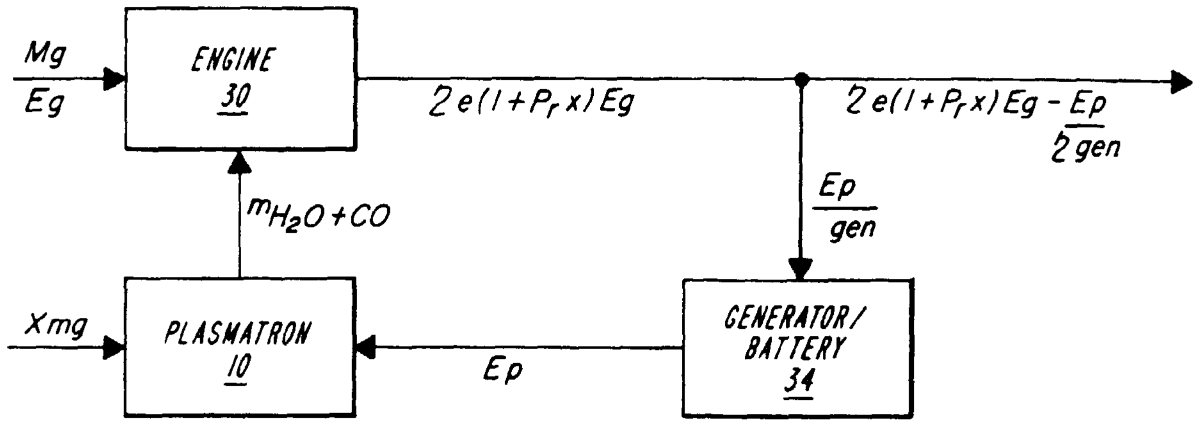
Mg
Eg
ENGINE
30
2e(1+Prx)Eg
2e(1+Prx)Eg - Ep / ?gen
Ep / gen
mH2O+CO
Xmg
PLASMATRON
10
Ep
GENERATOR/
BATTERY
34

FIG. 7

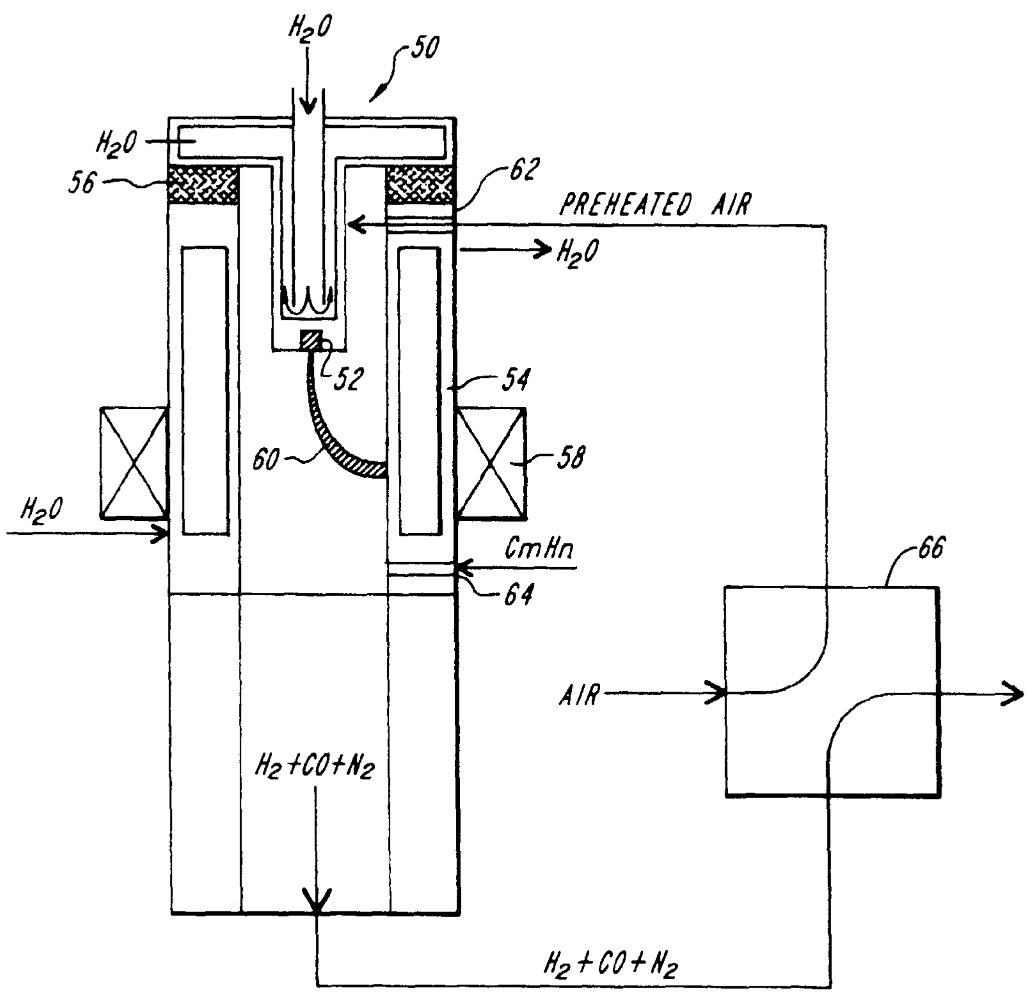
H2O
50
H2O
56
62
PREHEATED AIR
H2O
52
54
60
58
H2O
CmHn
64
66
AIR
H2+CO+N2
H2+CO+N2

FIG. 8

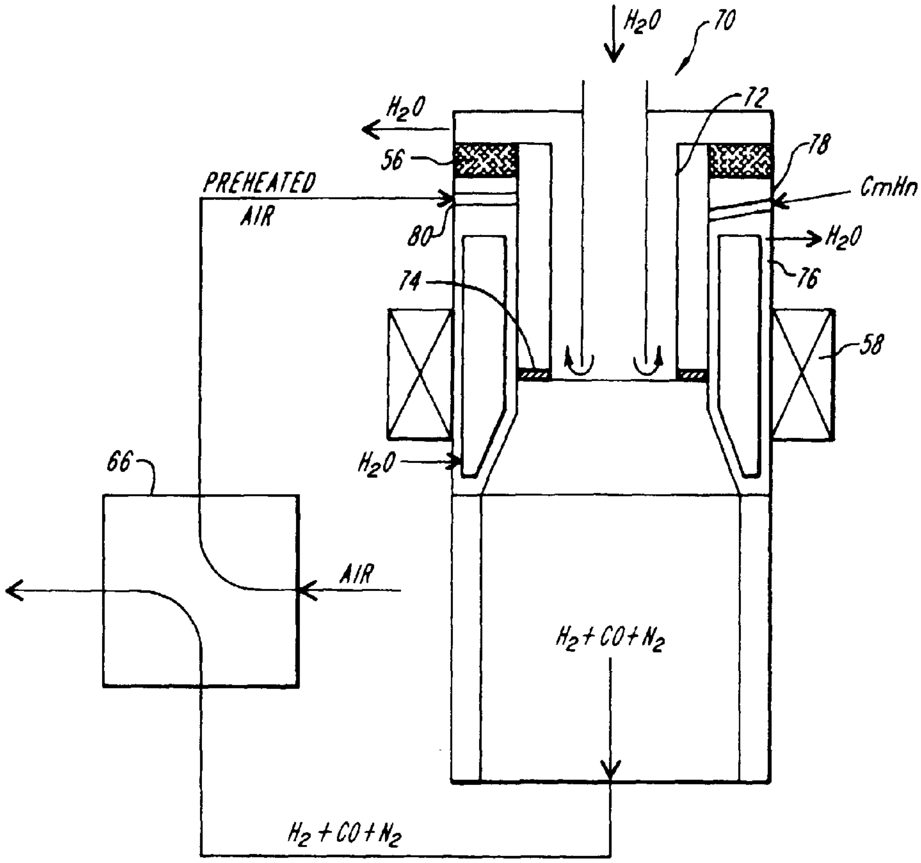
H2O
70
H2O
72
56
78
PREHEATED AIR
CmHn
80
H2O
74
76
58
66
H2O
AIR
H2+CO+N2
H2+CO+N2

FIG. 9

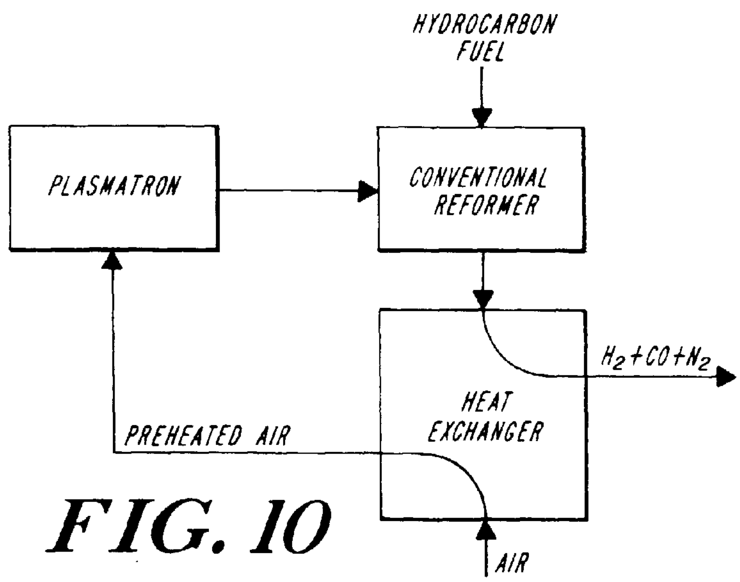
HYDROCARBON FUEL
PLASMATRON
CONVENTIONAL REFORMER
H2+CO+N2
HEAT EXCHANGER
PREHEATED AIR
AIR

FIG. 10